



# GENOTYPIC ANALYSIS AND ASSOCIATION AMONG LEAF AREA, LEAF AREA INDEX AND TOTAL DRY MATTER PRODUCTION OF COTTON UNDER WATER STRESS CONDITION

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## ABSTRACT

Drought severely affects plant growth and development with substantial reductions in leaf area, leaf area index and biomass accumulation. The main consequences of drought in crop plants are reduced rate of cell division and expansion, leaf size, stem elongation, plant water and nutrient relations with diminished crop productivity. Adequate soil moisture is essential for successful crop production. Water stress and other abiotic stresses can dramatically limit plant growth and productivity. The growth parameters such as leaf area, leaf area index and total dry matter production were significantly affected by drought stress. Water-use efficiency (WUE) is a key factor determining plant productivity under limited water supply. The aim of the present study was to understand the effect of water stress on leaf area, leaf area index and total dry matter production of cotton genotypes. The experiment was conducted by adopting Factorial Randomized Block Design with three replications. The treatments comprised of water stress imposed at vegetative, squaring and boll development stages of crop growth.

**KEY WORDS:** Drought, Drought Tolerance, Leaf area, Leaf area index and Total dry matter production

## INTRODUCTION

Water stress is commonly attributed to situations where the water loss exceeds sufficient absorption intensity causing a decrease in plant water content, a decrease in cellular expansion and alterations of various physiological processes that can affect growth or productivity. *Gossypium hirsutum* L. and *Gossypium barbadense* L. are the two predominant elite cotton species, usually grown during the summer in arid and semiarid regions where water availability is often limited. Regardless of whether it is irrigated or not, cotton is often exposed to drought, which adversely affects both yield and lint quality. Improving the water use efficiency of cotton plants could reduce the adverse effects of drought and also improve productivity under non-stressful conditions.

## MATERIALS AND METHODS

The aim of this experiment was to investigate the responses caused by progressive water stress and the necessary time for have biochemical and physiological changes of *Gossypium* spp. during the vegetative, squaring and boll development stages. For present investigation, twenty one genotypes including eight parents, four  $F_1$  hybrids, five  $F_2$ 's and four back crosses along with parents were subjected for genetic diversity analysis using physiological features. Field trails were conducted in at Kharif 2008 in the Department of Cotton, Centre for Plant Breeding and Genetics, TNAU, Coimbatore.

### Treatments

1.  $T_1$ - Control
2.  $T_2$ - Stress at vegetative
3.  $T_3$ - Stress at squaring
4.  $T_4$ - Stress at boll development

### Genotypes and Varietal Details:

Parents	F1 Hybrids	F2's	Back Crosses
1. JKC 770	1. AS1XSuvini	1. KC2XMCU 13	1.(AS2XMCU13)
2. AS1	2. KC2XMCU 13	2. AS3XJKC 770	XMCU13
3. AS2	3. AS2XMCU13	3. AS2XMCU 13	2. (AS2XMCU13) X
4. KC2	4. KC2X JKC 770	4. KC2XJKC 770	AS2
5. KC3		5. AS1XSuvini	3.(KC2XMCU 13)X
6. MCU 13			MCU 13
7. Suvin			4. (KC2XMCU13)
8. Surabhi			XKC2

### Leaf Area (LA)

Leaf area for the whole sampling unit was measured by using Leaf Area Meter (Li-Cor Model 3100) and expressed as  $cm^2 plant^{-1}$ .

Leaf area estimation based on leaf dimensions such as length and width has also been used. Winter and Ohlrogge (1973), Krishnamurthy *et al.* (1974), this method can be nondestructive because the leaf dimensions necessary for estimating leaf area can be measured on intact leaves.

### Leaf Area Index (LAI)

From randomly selected plants in each treatment plot, leaf length and maximum width of the third leaf from the top was measured by five representative samples. Total number of leaves in each plant was counted. From these observa-

tions made on 60, 90, 120 DAS and at harvest stage, the LAI was calculated using the following formula as suggested by Ashley *et al.* (1965).

$$LAI = \frac{L \times W \times N \times 0.775}{\text{Land area (cm}^2\text{) occupied by one plant}}$$

Where,

L = Length of the leaf in cm, W = Width of the leaf in cm,

N = Number of the leaves per plant and

0.775 = Constant value

### Total Dry Matter Production (TDMP)

Five plants at random were cut at ground level for estimating of dry matter production. The samples were initially air dried for 24 hours and subsequently dried in oven for further 24 hours at  $60 \pm 5^\circ C$  to get a constant weight. The weights were recorded on moisture free basis and expressed in  $kg ha^{-1}$ .

## RESULTS AND DISCUSSION

A reduction in cell growth is one of the earliest effects of water deficit. This, in turn, results in smaller leaves on stressed plants (Begg, 1980). Measurement of leaf area is basic tool of growth analysis and it is directly related with both biological and economic yield, besides influencing rate of photosynthesis. The mean data recorded at various growth stages indicated that there is significant reduction in leaf area under water stress compared to control (From 692.28 to 672.95 (2.97%) – vegetative, 979.95 to 938.97 (4.36%) – squaring, 1657.31 to 1552.29 (6.76%) – boll development in  $F_1$ ,  $F_2$  and back crosses along with parents. The differences are statistically significant. The genotype MCU 13 maintains a higher mean leaf area during boll development stage than others even under the stress condition (1764). The mean data recorded at various growth stages indicated that there is significant reduction in leaf area under water stress compared to control. Parsons (1994) reported that reduction in LA is a common feature is an adaptive mechanism to tide over drought condition. In the present investigation, a similar trend was observed wherein stress given at any stage reduced the LA. However the tolerant genotypes had shown less reduction when compared to susceptible genotypes. The genotype KC2XMCU13( $F_4$ ) performed well under water stress conditions since it had little decrease in leaf area under water stress conditions (1589 to 1466) at boll development stage.

Soil moisture deficit stress reduces cotton plant stature and LAI, promoting an accompanying reduction in the solar radiation intercepted by the canopy. The reduced plant stature and LAI under moisture deficit stress are similar to that reported by Turner *et al.* (1986). Although there is less leaf area intercepting, a reduced portion of the incoming solar radiation, leaves from dry land plants have the potential for elevated photosynthetic performance during the morning hours when the hydraulic status of the plants is still at an acceptable level (Pettigrew, 2004). Water deficit condition at all the stages significantly decreased the leaf area index than the control. The treatments were found to be significant among the genotypes, treatments as well as their interaction effects. The genotype MCU13 has the highest value (0.133, 0.184 and 0.330) than other genotypes at all stages irrespective of the treatment effects. The leaf area index progressively increased over the crop growth stages regardless of stress or control condition (from 0.127 to 0.297 – in  $F_1$ ,  $F_2$  and back crosses along with parents).

Water deficit conditions during all stages significantly reduced the TDMP than in the control irrespective of the genotypes. The genotype KC2 performed well under drought condition with less reduction in TDMP (from 444.27 to 391.21). Klepper *et al.* (1973) reported that water stress in cotton was found to have profound effect in reducing the plant growth and ultimately TDMP gets reduced. The reduction in TDMP was observed to be directly related to a concomitant decrease in leaf area as was reported by Sahay (1989). Singh and Bharatwaj (1983) observed that water stress has pronounced effect during flowering stage of cotton. In the present investigation, stress invariably has affected an overall reduction in TDMP irrespective of genotypes. KC 2 X MCU 13 ( $F_2$ ) recorded the highest TDMP values of 567.29 followed by the genotype Suvin.

### Conclusions

The growth parameters such as leaf area, leaf area index and total dry matter production were significantly affected by drought stress. A reduction in cell growth is one of the earliest effects of water deficit. This, in turn, results in smaller leaves on stressed plants. The mean leaf area was found to be reduced under stress compared to the control. The genotype MCU13 maintains a higher leaf area and leaf area index in boll development stage than others even under the stress condition. KC2 X MCU13 and Suvin followed by KC2 performed well under drought condition with less reduction in total dry matter production. The reduction in total dry matter production was observed to be directly related to a concomitant decrease in leaf area.

**Table 1. Effect of drought on leaf area (cm<sup>2</sup> plant<sup>-1</sup>) at different stages of cotton in  $F_1$ ,  $F_2$ , back crosses along with parents**

Stages	Vegetative					Squaring					Boll Development				
Genotypes															
Parents	T1	T2	T3	T4	Mean	T1	T2	T3	T4	Mean	T1	T2	T3	T4	Mean
MCU 13	716.73	658.23	713.71	704.47	698.29	992.50	974.89	926.05	989.39	970.71	1783.55	1764.50	1761.39	1746.89	1764.08
AS 2	678.02	665.19	671.98	633.51	662.18	953.79	936.18	933.01	950.68	943.42	1744.84	1725.79	1722.68	1708.18	1725.37
JKC 770	624.18	624.85	569.07	641.7	614.95	887.38	869.77	874.67	884.27	879.02	1645.00	1631.38	1628.27	1613.77	1629.61
KC 2	701.39	701.62	700.74	699.62	700.84	964.19	945.30	951.44	960.74	955.42	1721.01	1708.19	1704.74	1689.30	1705.81
AS 1	677.14	680.26	667.08	670.26	673.69	939.94	920.15	930.74	936.02	931.71	1697.42	1683.94	1680.02	1664.15	1681.38
Surabhi	616.41	632.11	693.09	650.25	647.97	875.46	855.99	882.59	871.86	871.48	1628.69	1611.46	1607.86	1591.99	1610.00
KC 3	679.01	684.81	681.07	683.65	682.14	938.26	918.79	941.29	934.66	933.25	1697.89	1674.26	1670.66	1654.79	1674.40
Suvin	693.22	627.65	697.95	695.41	678.56	952.47	933.00	884.13	948.87	929.62	1712.10	1688.47	1684.87	1669.00	1688.61
<b><math>F_1</math> Hybrids</b>															
AS1 X Suvin	737.22	724.86	749.39	753.21	741.17	1045.38	1040.30	1013.77	1037.98	1034.36	1734.32	1582.70	1726.92	1618.64	1665.65
KC 2 X MCU 13	718.6	770.54	727.69	719.34	734.04	1027.15	1006.43	1057.39	1016.28	1026.81	1716.09	1626.32	1705.22	1584.77	1658.10
AS 2 X MCU 13	729.12	709.76	738.42	735.27	728.14	1039.21	1022.36	998.13	1027.01	1021.68	1728.15	1567.06	1715.95	1600.70	1652.97
KC 2 X JKC 770	730.73	719.94	745.68	737.51	733.47	1040.12	1024.60	1018.07	1034.27	1029.27	1729.06	1587.00	1723.21	1602.94	1660.55
<b><math>F_2</math>S</b>															
KC 2 X MCU 13	702.82	687.54	708.38	715.68	703.61	1047.75	966.55	964.84	983.36	990.63	1578.38	1491.46	1560.23	1460.25	1522.58
AS 3 X JKC 770	660.69	661.78	623.7	725.57	667.94	1005.62	976.44	939.08	898.68	954.96	1536.25	1465.70	1475.55	1470.14	1486.91
AS 2 X MCU 13	706.36	691.08	711.92	719.22	707.15	1051.29	970.09	968.38	986.90	994.17	1581.92	1495.00	1563.77	1463.79	1526.12
KC 2 X JKC 770	632.79	617.51	657.88	672.39	645.14	977.72	923.26	894.81	932.86	932.16	1508.35	1421.43	1509.73	1416.96	1464.12
AS 1 X Suvin	646.78	632.79	706.18	646.15	657.98	991.71	897.02	910.09	981.16	945.00	1522.34	1436.71	1558.03	1390.72	1476.95
<b>Back Crosses</b>															
(AS2XMCU13) X MCU13	668.79	646.19	664	670.39	662.34	943.19	931.06	893.31	913.48	920.26	1615.48	1481.61	1489.37	1399.51	1496.49
(KC2XMCU13) X KC2	691.07	661.98	674.11	683.79	677.74	965.47	944.46	909.10	923.59	935.66	1637.76	1497.40	1499.48	1412.91	1511.89
(AS2XMCU13) X AS2	664.73	633.84	659.85	663.62	655.51	939.13	924.29	880.96	909.33	913.43	1611.42	1469.26	1485.22	1392.74	1489.66
(KC2XMCU13) X MCU13	726.82	699.32	716.78	716.93	714.96	1001.22	977.6	946.44	966.26	972.88	1673.51	1534.74	1542.15	1446.05	1549.11
<b>Mean</b>	685.84	672.95	689.46	692.28	685.13	979.95	950.41	938.97	956.55	956.47	1657.31	1578.30	1619.78	1552.29	1601.92
SEd CD(P=0.05)	T 1.676 3.309	G 3.841 7.583		TXG 7.682 15.177		T 1.611 3.182	G 3.693 7.291		TXG 7.386 14.583		T 1.568 3.136	G 0.689 1.368		TXG 3.457 6.185	

Table 2. Effect of drought on leaf area index at different stages of cotton in F<sub>1</sub>, F<sub>2</sub>, back crosses along with parents

Stages	Vegetative					Squaring					Boll Development			
Genotypes														
Parents	T1	T2	T3	T4	Mean	T1	T2	T3	T4	Mean	T1	T2	T4	Mean
MCU 13	0.133	0.122	0.132	0.130	0.129	0.184	0.181	0.171	0.183	0.180	0.330	0.327	0.323	0.327
AS2	0.126	0.123	0.124	0.117	0.123	0.177	0.173	0.173	0.176	0.175	0.323	0.320	0.316	0.320
JKC 770	0.116	0.116	0.105	0.119	0.114	0.164	0.161	0.162	0.164	0.163	0.305	0.302	0.299	0.302
KC2	0.130	0.130	0.130	0.130	0.130	0.179	0.175	0.176	0.178	0.177	0.319	0.316	0.313	0.316
AS1	0.125	0.126	0.124	0.124	0.125	0.174	0.17	0.172	0.173	0.173	0.314	0.312	0.308	0.311
Surabhi	0.114	0.117	0.128	0.120	0.120	0.162	0.159	0.163	0.161	0.161	0.302	0.298	0.295	0.298
KC3	0.126	0.127	0.126	0.127	0.126	0.174	0.17	0.174	0.173	0.173	0.314	0.310	0.306	0.310
Suvin	0.128	0.116	0.129	0.129	0.126	0.176	0.173	0.164	0.176	0.172	0.317	0.313	0.309	0.313
<b>F<sub>1</sub> Hybrids</b>														
AS1XSuvn	0.137	0.134	0.139	0.139	0.137	0.194	0.193	0.188	0.192	0.192	0.321	0.293	0.300	0.308
KC2XMCU13	0.133	0.143	0.135	0.133	0.136	0.190	0.186	0.196	0.188	0.190	0.318	0.301	0.293	0.307
AS2XMCU13	0.135	0.131	0.137	0.136	0.135	0.192	0.189	0.185	0.190	0.189	0.320	0.290	0.296	0.306
KC2XJKC770	0.135	0.133	0.138	0.137	0.136	0.193	0.19	0.189	0.192	0.191	0.320	0.294	0.297	0.308
<b>F<sub>2</sub>'S</b>														
KC2XMCU13	0.130	0.127	0.131	0.133	0.130	0.194	0.179	0.179	0.182	0.183	0.292	0.276	0.270	0.282
AS3X JKC770	0.122	0.123	0.116	0.134	0.124	0.186	0.181	0.174	0.166	0.177	0.284	0.271	0.272	0.275
AS2XMCU13	0.131	0.128	0.132	0.133	0.131	0.195	0.18	0.179	0.183	0.184	0.293	0.277	0.271	0.283
KC2XJKC770	0.117	0.114	0.122	0.125	0.119	0.181	0.171	0.166	0.173	0.173	0.279	0.263	0.262	0.271
AS1XSuvn	0.120	0.117	0.131	0.120	0.122	0.184	0.166	0.169	0.182	0.175	0.282	0.266	0.258	0.274
<b>Back Crosses</b>														
(AS2XMCU13)XMCU13	0.124	0.120	0.123	0.124	0.123	0.175	0.172	0.165	0.169	0.170	0.299	0.274	0.259	0.277
(KC2XMCU13)XKC2	0.128	0.123	0.125	0.127	0.126	0.179	0.175	0.168	0.171	0.173	0.303	0.277	0.262	0.280
(AS2XMCU13)XAS2	0.123	0.117	0.122	0.123	0.121	0.174	0.171	0.163	0.168	0.169	0.298	0.272	0.258	0.276
(KC2XMCU13)XMCU13	0.135	0.13	0.133	0.133	0.132	0.185	0.181	0.175	0.179	0.18	0.31	0.284	0.268	0.287
<b>Mean</b>	0.127	0.125	0.128	0.128	0.127	0.182	0.176	0.174	0.177	0.177	0.307	0.292	0.287	0.297
SEd CD(P=0.05)	T 0.009 0.018	G 0.002 0.043		TXG 0.004 0.086		T 0.001 NS	G 0.002 NS		TXG 0.005 NS		T 0.001 0.003	G 0.004 0.008		TXG 0.008 0.017

Table 3. Effect of drought on TDMP (g plant<sup>-1</sup>) content at boll development stage of cotton in F<sub>1</sub>, F<sub>2</sub>, back crosses along with parents

Stages	Harvest stage				
Genotypes					
Parents	T1	T2	T3	T4	Mean
MCU 13	393.42	383.91	383.68	382.12	385.78
AS 2	403.98	389.13	378.89	380.83	388.21
JKC 770	394.14	365.84	373.31	353.78	371.77
KC 2	444.27	408.67	388.72	391.21	408.22
AS 1	425.56	350.82	412.31	353.88	385.64
Surabhi	453.2	354.17	428.31	348.4	396.02
KC 3	353.48	333.68	339.08	334.18	340.11
Suvin	487.21	476.93	453.90	401.42	454.87
<b>F<sub>1</sub> Hybrids</b>					
AS1 X Suvin	388.33	300	323	301	328.08
KC 2 X MCU 13	563.2	437.29	342.76	410.01	438.32
AS 2 X MCU 13	267.88	254.89	265.78	265.67	263.56
KC 2 X JKC 770	389.78	296.7	376.89	315.2	344.64
<b>F<sub>2</sub>'S</b>					
KC 2 X MCU 13	567.29	489.52	502.82	517.54	519.29
AS 3 X JKC 770	515.45	489.67	398.45	455.65	464.81
AS 2 X MCU 13	345.33	210.77	225.32	230.81	253.06
KC 2 X JKC 770	290.39	198.46	243.25	270.6	250.68
AS 1 X Suvin	496.21	458.25	386.90	421.44	440.70
<b>Back Crosses</b>					
(AS2 X MCU13) X MCU13	390.72	275.44	325.56	270.73	315.61
(KC2 X MCU13) X KC2	367.23	367.41	334.10	345.20	361.032
(AS2 X MCU13) X AS2	278.455	256.12	245.56	219.53	249.92
(KC2 X MCU13) X MCU13	356.63	379.52	348.33	345.02	337.49
<b>Mean</b>	407.15	353.74	356.04	350.66	366.56
SEd CD(P=0.05)	T 2.180 4.308	G 4.998 9.871		TXG 9.999 19.749	

## REFERENCES

1. \*Parsons, A.N., J.M. Welker, P.A. Wookey, M.C. Press, T.V. Callaghan and J.A. Lee. 1994. Growth responses of four sub-arctic dwarf shrubs to simulated environmental change. **The Journal of Ecology**, **82**(2): 307-318.
2. Begg, J.E. 1980. Morphological adaptations of leaves to water stress. In NC Turner, PJ Kramer, eds, *Adaptation of Plants to water and High Temperature Stress*. John Wiley and Sons, New York. Pp 33-42.
3. Klepper, B., H.M. Taylor, M.G. Huck and E.L. Fiscus. 1973. Water relations and growth of cotton in drying soil. **Agron. J.**, **65**: 307-310.
4. Krishnamurthy, K., M.K. Jagannath, B.G. Rajashekara, and G. Rag hunatha. 1974. Estimation of leaf area in grain sorghum from single leaf measurements. **Agron. J.** **66**:544-545.
5. Pettigrew, W.T. 2004. Moisture deficit effects on cotton lint yield, yield components and boll distribution. **Agron. J.**, **96**: 377-383.
6. Pettigrew, W.T. 2004. Physiological consequences of moisture deficit stress in cotton. **Crop.Sci.**, **44**: 1265-1272.
7. Sahay, R.L. 1989. Photosynthetic and stomatal response of cotton to drought stress and water logging. **Agric. Sci. Digest.**, **9**(4): 198-200.
8. Singh, D. and S.N. Bhardwaj. 1983. Physiological analysis of yielding ability in hirsutum cotton. II. Parameters controlling dry matter accumulation, boll number and seed cotton yield. **Indian J. Plant Physiol.**, **18**: 264-275.
9. Turner, N.C., A.B. Hearn, J.E. Begg and G.A. Constable. 1986. Cotton (*Gossypium hirsutum*). Physiological and morphological response to water deficits and their relationship to yield. **Field Crops Res.**, **14**: 153-158.